

**Some modern aspects of the physics of strongly
correlated electron systems**

**Instituto Universitario de Ciencia de Materiales
"Nicolás Cabrera"
de la
Universidad Autónoma de Madrid**

F. G. Aliev, J. C. Gomez-Sal, H. Suderow, R. Villar (Eds.)

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Introduction

Dear Reader,

When the Director of the Research Institute of Materials Science "Nicolás Cabrera", Prof. Sebastián Vieira, asked me to organize the sixth international school of the Institute, the challenge seemed huge to me. However, from the very beginning, the response both from the invited speakers as from the sponsors was extraordinary. Later on, this positive reception was followed by the students who attended the school. The success of this meeting is their merit.

All the lecturers made a special effort to combine the highest scientific level with a pedagogical approach and even with good humor, and we feel very grateful for it. This provoked fruitful discussions, from which we have learned a lot and which we enjoyed much. The session devoted to the exposition by all the students of their own research was specially instructing, because it showed that we belong to a pushing and lively community of physicists.

We enjoyed sharing a week of learning in the beautiful residence "La Cristalera" from the Universidad Autónoma de Madrid, which lies on the mountains near to the city in a marvelous site. The weather was nice, and fresher than in town, and the trip to La Granja, Segovia and the conference dinner were exciting for all. So that besides physics we cultivated friendship.

The field of Strongly Correlated Electron Systems covers nowadays a large number of different subjects within Condensed Matter Physics. Indeed, correlations between electrons are most probably in the origin of High Temperature Superconductivity, but also give rise to a very large number of interesting effects in modern magnetism. At this School, we have learned about the interest and the difficulties of $T=0\text{K}$ Quantum Phase Transitions oc-

curing in magnetic systems, about the amazing superconducting properties of some Strongly Correlated Electron Systems and about the interesting interplay between superconductivity and magnetism. Some other aspects of the magnetism, as well as some technical tools used to investigate these materials were also discussed.

Some of the speakers have been able to put on black over white their lectures and this book is the fruit of that additional work, which we thank additionally.

In the first part of this book, we introduce the main subject of debate in the School, the zero temperature Quantum Phase Transitions. The work of Prof. Arkadii Levanyuk is an excellent introduction to the field, as it presents in detail a simple case, which can be solved exactly, and where the difficulties and interest of the problem is made clear. Prof. Bernard Coqblin and collaborators present an introduction to the subject and a view of their new theories. Prof. Hilbert von Löhneysen gives a review of a large amount of experimental work and its relevance for current theories. Prof. Brian Maple describes the case of Uranium compounds and gives an extensive review. Prof. Antonio Castro-Neto presents a very extended theoretical paper that treats the problem in detail, giving a very large number of references and comments. Finally, Prof. Jacques Flouquet outlines the new trends and the necessary experimental improvements to further advance in the subject.

The second part gives some selected contributions to the problem of magnetism in complex systems. Prof. Francisco Guinea points to the importance of phase separation near magnetic transitions, and the contribution of Prof. Andrey V. Chubukov gives an example for the interplay between magnetism and superconductivity in Strongly Correlated Electron Systems. This sets a bridge to the next part of the book.

In the third part, the authors describe the interesting properties of superconducting Strongly Correlated Electron Systems. Prof. Jean Pascal Brison presents a pedagogical introduction to the so-called non-conventional superconductors, focusing on the symmetry breaking occurring in these systems. Prof. Alexander I. Buzdin presents a theoretical overview of the possible realization of novel high field phases, different from the ones appearing in

conventional superconductors. Prof. John R. Kirtley presents impressive microscopic experiments, where the new properties of unconventional superconductors are most clearly demonstrated.

Finally, this book is finished with the contributions of two experimentalists, Prof. Erwin Bauer and Prof. Jesús Chaboy who present several aspects of high pressure and synchrotron radiation techniques applied to Strongly Correlated Electron Physics.

This enterprise would have ended as a disaster, had it not been for the enthusiastic and dedicated work of my collaborators: Farkhad Aliev and Hermann Suderow from the Laboratory of Low Temperature Physics of the Institute, also headed by Sebastián Vieira, Pepe Carlos Gómez Sal from the Universidad de Cantabria, and Beatriz Renes, secretary of the Institute, always helpful and charming. I also need to mention the publication service of our University (and especially D. Saavedra) which made a significant contribution by working on the original files to put them in a nice format.

In the School we had 18 invited lecturers and it was attended by 42 students, most of them graduate, from 15 different countries, and around one third from Spain. Thus it has turned out to be a really international summer school of the highest level.

I am sure that these Proceedings will be very valuable for many graduate students working in this promising field, and will also be a helpful tool for many researchers as a reference material.

Raúl Villar

Director of the VI Summer School Nicolás Cabrera

List of Invited Lecturers

- E. Bauer *Pressure response on Strongly Correlated Electron Systems*
- J.P. Brison *Unconventional Superconductivity in Heavy Fermion systems*
- A.I. Buzdin *Non uniform Superconductivity under High Magnetic fields*
- A. Castro-Neto *Disorder close to quantum critical points : Griffiths singularities and Non-Fermi liquid behavior in SCES*
- J. Chaboy *X Ray Absorption Spectroscopy on Strongly Correlated Electron Systems*
- A. Chubukov *Spin fluctuation theory of High temperature superconductivity*
- B. Coqblin *Magnetism and Heavy Fermions in Strongly Correlated Electron Systems*
- J. Flouquet *The magnetic field crossover in heavy fermion systems*
- F. Guinea *Phase separation near magnetic transitions*
- R. Iglesias *Competition between magnetic order and Kondo effect in Ce compounds*
- A.G.M. Jansen *Point contact spectroscopy*
- S.R. Julian *Introduction to magnetic quantum critical metals: from non-Fermi liquid to exotic superconductors*
- J.R. Kirtley *Studies of High-Tc superconductors with the Scanning SQUID microscope*
- A. Levanyuk *Introduction to Zero- and Low-Temperature Phase Transitions*
- H.v. Löhneysen *Quantum Phase Transitions in Strongly Correlated Electron Systems*
- B. Maple *Non Fermi liquid behavior in f-electron metals*
- K.A. McEwen *Neutron scattering and SCES*
- Yu. Pogorelov *Magnetism of Nanostructured Systems*